GEOGRAPHICAL INFORMATION SYSTEMS AS A TOOL FOR INCIDENT MANAGEMENT

Paul Woods MCGI MIFireE
Deputy Chief Fire Officer
Nottinghamshire Fire and Rescue Service
E-mail: pandd.woods@btinternet.com

ABSTRACT

Information is one essential component in determining the successful outcome of fire and other large-scale incidents. Successful incident command requires the co-ordination of human and other resources. The incident commander must assimilate information from a number of different sources, including pre-incident plans and other on-scene commanders, and then determine an appropriate strategy. Geographical Information Systems (GIS) and other technologies can assist with both the storage and management of pre-incident and dynamic information needed to enable effective command to take place. GIS is still an underused resource in the arena of incident management. Given the complexities and stresses of fireground command, it is vital that every opportunity is taken to enable successful outcomes to be achieved.

INTRODUCTION

The fire service in the United Kingdom operates under statute. The Fire Services Act 1947 requires that Local Authorities (County Councils, Combined Fire Authorities and Fire & Civil Defense Authorities) organize and run an effective fire service, with the means to handle emergency calls and train employees. In 1974 legislation was introduced to deal with the health and safety of people at work. More recently, the Management of Health and Safety at Work Regulations 1992 introduced new areas for employers to consider in relation to safety. Risk assessment was introduced as the tool to determine the hazards faced by employees and the measures necessary to mitigate them. Personal Protective Equipment Regulations that cover firekit (turnout gear) were introduced around the same time. Such risk assessments formally extend the 'place of work', traditionally viewed as the fire station itself, to the incident ground.

The Fire Services Act 1947 Section 1.i.d. requires fire Brigades to:

> *"Secure efficient arrangements for obtaining by inspection or otherwise information required for firefighting purposes with respect to the character of buildings, available water supplies and the access thereto, and other material circumstances"*

A public inquiry into a major fire at the King's Cross Underground Station in London in 1989, which claimed the lives of 13 people including a firefighter, criticized the London Fire Brigade for inadequate pre-event tactical planning. The injury highlighted the fact that the Brigade had not undertaken sufficient and appropriate visits to the underground network in accordance with Section 1.i.d. of the Fire Services Act.

Due to the fact that technology was not readily applied to meet this need, the quality and extent of the information varied. In many cases topographical visits were used to gather the information and personal memory used to store it. In the majority of brigades information was stored on both sides of an A4 card, one side containing textual information on the site, the other a simple plan. Following the deaths of two firefighters in a factory fire in 1993, the Health and Safety Executive (the equivalent of OSHA in the United States) issued 'improvement notices' to the employing Brigade. Those notices ordered the Brigade to review its safety procedures and to implement improvements. One major citation within the notices dealt with the lack of information on the factory available to officers and crews at the fire.

The fire service nationally was compelled to act upon the outcomes of both of those investigations and the Health and Safety legislation that followed. Fire Brigades have since sought to introduce effective pre-event information gathering and tactical planning procedures. Geographical Information System (GIS) technology has enabled the fire service to meet those needs in combination with new Incident Command Systems (ICS) procedures. GIS coupled with other technologies can enable the service to effectively discharge its duty to both the public and its employees. The development on an ICS should be seen as part of a Brigade's overall organizational system for managing risk.

INCIDENT COMMAND SYSTEMS (ICS)

The fire service is tasked with the saving of life, protection of property and the protection of the environment from the effects of fire and other disasters, both man-made and natural. As technological risk increases so too does the role of the service in dealing with large-scale chemical incident and other hazardous non-fire scenarios.

The effect of the combination of fire and chemical was never more apparent than at an incident in Basle in 1986. Following a major fire in the Sandoz chemical plant, the Rhine River was contaminated by firefighting run-off. The resultant pollution crossed international frontiers. The European-wide legislation that followed in the form of the Seveso Directive, requiring major industrial sites to plan with the fire service and others to deal with emergencies both on, and potentially, off-site. Successful incident command at these and other incidents involves the co-ordination of human and other resources, together with a number of other factors. Resource management will include those of other agencies and organizations on scene.

Successful incident command requires a number of key components to be combined simultaneously. These include, in addition to those already mentioned, communications, and information, all of which enable the strategy, tactics and operations to be implemented. Strategic responsibility involves the formulation of systems to achieve the desired objectives. Tactics are the methods of deploying resources to achieve the strategy. Operations are the component tasks of the tactical implementation of a plan.

The successful management of any incident, large or small, is dependent upon the Incident Commander being able to formulate a plan of campaign and brief subordinated commanders accordingly and effectively. The plan must be implemented in a coordinated way, involving the application of appropriate spans of control. The number of crews will generally escalate as the size of the incident increases, requiring a greater degree of control to be implemented. The Incident Commander must be able to brief sector and crew commanders and to receive updates as to progress against the plan and any changes in circumstances that require the plan to be amended.

The ICS model applied in the UK focuses on the sectorization of an incident ground with command officers assigned to each one. Subordinate officers control crews operating within sectors and report to the sector commander. All sector officers are briefed by and report to the Incident Commander. A number of functional officers are also appointed in support of the Incident Commander. Water supplies, safety, breathing apparatus and other equipment, press liaison, communications, and more are examples of functional responsibility. The number and range of these officers is dependent upon the scale of the incident being dealt with.

In the UK incident command support is provided by purpose built vehicles. Dedicated personnel operated within an Incident Command Unit (ISU) to support officers on the incident ground. ISUs generally have facilities for radio/telephone communication, conference and briefing meetings, and resource deployment boards.

Local area maps and plans, together with water supply information is also stored on such vehicles. One of the criticisms of the above fire that brought in the Health & Safety Executive was the fact that risk information was not available to crews in the earliest stages of the incident. Most fire Brigades in the UK only have one such vehicle that is mobilized when a given number of appliances are on scene. The future rests with the ability to provide all mobiles with sufficient and timely information.

The effective combination of pre-incident and dynamic information, together with ICS is a prerequisite to the accomplishment of the desired outcomes at any fire or other emergency scene, regardless of size. Technology has enabled the storage of large volumes of data in relatively small units thereby enabling all mobile vehicles to access much needed information.

INCIDENT GROUND INFORMATION

Information is a vital component of successful incident management. Information needs can be considered in three incident stages: before, during and post incident. As was demonstrated by the incidents referred to above there is a need to gather hazard information and consider tactics before the event. Given the number of risk sites within a Brigade's operating area, the selection of the method of storage and retrieval is important. The ease with which information can be gathered will affect the quality of the result.

A methodology has been devised for Nottinghamshire with which to assess the risk posed by individual sites and therefore the scale of information required relative to them. Pre-event information is held and used

in three tiers:

- For use by the Officer in Charge initial response team
- For use by the on scene commander
- For major incidents involving a multi-agency response

One important aspect of the process developed for the collection and use of information to support incident command, is the fact that the Brigade policy has to identify how and when such information is to be used, and by whom. It is pointless having any such information if officers in charge of incidents do not use it. How often have site and building plans laid dormant in fire prevention offices or appliance cabs until after the incident? Risk site information must be as integral to the support of incident ground decision-making as Standard Operating Procedures (SOPs).

In addition to the pre-event information, officers in charge will be presented with dynamic information on arrival and during subsequent operations. The officer in charge will need to assimilate information from a number of different sources, including site occupants, on scene commanders, other emergency services and agencies. Strategic plans and tactics may be amended on the strength of such information. This paper will deal with the opportunities for information and resource management (Command and Control) through the use of GIS, together with an examination of the complementary technologies available to enable effective incident command.

GEOGRAPHICAL INFORMATION SYSTEMS

A Geographical Information System (GIS) is a computer-based tool for mapping and analyzing information. GIS was developed and grew in parallel with the expansion of the computer industry through the 1970s and 1980s. In the 1990s several factors including the dramatic fall in hardware prices, led to major advances in their usability and access. GIS can combine data from diverse origins into consistent displays represented as different layers, each holding a particular feature e.g. hydrants. The data is stored and organized so as to integrate easy access, querying and filtering with unique visualization and geographic analysis benefits offered by maps.

A typical installation will provide full County coverage at 1:625,000, 1:50,000, 1:10,000, 1:2,500 and 1:1,250 scale. GIS allows multiple views to be accessed and displayed simultaneously on different windows on the screen. Multiple scale views can be interacted with, moved, rescaled, and iconised within a single user session. Powerful gazetteer facilities are available within any scale. In essence, GIS is an extremely efficient way of managing data overload on top of map backgrounds, with access to powerful features. The power and memory of today's computers allows this to be done in real time.

GIS can also keep a log of its operations. Those logs can keep trace of everything that happened on the system and can therefore be used to analyze events during the incident debriefing. This is an important aspect of incident management that is often overlooked. Safety, ICS and training needs can be identified during such processes and fed into the policy loop. In these litigious days such information can also assist at public inquiries or in compensation claims.

GEOGRAPHICAL INFORMATION SYSTEMS AND INCIDENT COMMAND

In response to the need for information management and ICS to be combined, more Brigades are looking to GIS as a solution. The decline in the defense market has forced manufacturers to find alternative outlets for their products. The emergency services are opening up as potential new customers for their wares. The fire service in the UK has seen the arrival and use of rugged computers, designed for use in tanks and armored military vehicles, in both appliances and cars. Global Positioning Satellite Systems (GPS) are now widely available in civilian applications and with increasing precision. The capacity and speed of modern computers is now such that the most complex of documents can easily be stored and used. Satellite communications, microwave technology and digital GSM phones, enable the transmission of data between base stations and mobiles.

In general fire service terms, Command and Control Systems operate in three arenas: at the Mobilizing Control Centre (MCC) from where appliances are mobilized, on Incident Support Units used at larger incidents, and in vehicle mounted units. GIS is used initially within the MCC as a mapping tool to identify an incident location, by converting the given address into a 12 digit grid reference and assigning appropriate resources to it. From the location identified this system finds and identifies the nearest and most appropriate appliances and officers to be sent based on what is called a predetermined attendance e.g. a single dwelling house would attract the attendance of 2 appliances and an additional officer.

Call handlers have the opportunity to identify the location and surrounding landmarks on the GIS, giving them the ability to interrogate the caller for more information and cross-references if required. They are also able to identify whether or not the site has risk or other information assigned to it signified by an icon or symbol attached to it. The icon or symbol type will reveal if the site has a chemical or radiation risk, or if tactical or fire prevention plans exist.

Such information will be passed to the responding appliances as part of their turnout instructions. MCC staff can access chemical and radiation database information relative to the identified substances and provide emergency action procedures to crews.

ISUs are mobilized when the attendance at an incident equals or exceeds fire appliances. GIS systems held at the MCC are mirrored on the ISU for use at the incident scene. The Incident Commander, Sector Officers and Functional Officers can print off all information for use. In addition to GIS and other command facilities, ISUs have TV reception capability.

Vehicle mounted units carry smaller map bases and less pre-incident information. These units use an integrated touch screen to keep typing to a minimum. The map showing the location of the current incident is displayed before the Officer in Charge boards the appliance. This is achieved by using the same signal that alerts the station to the call. It is intended that the Officer in Charge have sufficient information to enable them to get to the incident and initiate action on arrival, in consideration of an escalating incident with additional resources en route. Vehicle mounted systems also carry a hazardous information database giving emergency action codes for chemical protection and incident containment. Thermal printers in the cabs enable Crew Commanders to download hard copy of plans, hazard information and operational procedures. All such systems can be kept up to date by the use of computer networks between headquarters and individual fire stations. Stations will have either infrared or cable connections to the computers on board appliances, to give simultaneous update from the MCC as new information is received.

WHAT CAN GIS OFFER ICS?

The above demonstrates the link between incident command and GIS, showing a staged approach to information provision. This next section is intended to show what GIS can offer to the Incident Commander to assist the decision making process at an incident. GIS has the capacity to store maps and associated information, handle complex documents and other files, integrate external applications and display the results graphically.

The user can manipulate these in turn. In an ISU at the scene, an Incident Commander has access to the detailed maps of the area in which the incident occurs, together with overlays showing the locations and supporting data on items such as:

- Fire hydrants
- Telephone kiosks
- Static water supplies
- Radiation and chemical risk sites and storage location
- Gas and electricity distribution networks
- Rendezvous points

There are others. For each location, an icon or symbol marks the specific item. By selecting the icon of interest, the associated data is displayed. Icons used to identify a site of special interest such as a process plant, will reveal a menu of options including, still photographs, video clips, fire prevention plans, tactical plans, salvage plans and standard operating procedures and other documents. All documents can be printed if required. The Incident Commander at the scene will normally divide the incident into a number of sectors, depending on its size and complexity. Sector commanders can be given information specific to their sectors, with the incident commander having an overview. A photo to enable orientation and coordination accompanies each sector information plan.

Functional officers can be provided with operating procedures for their particular activity or specialism, together with their own plans of the scene. For example, a water officer can view the location of every major water supply in the area, together with its capacity and distance from the incident. Pre-event planning will have identified the number of intermediate pumps required to relay water and the length of the hose lines. GIS can do the hose line calculations based on ‘centre line of road’ calculations performed within the system.

Marshalling officers can also have their own incident plans showing the locations of pumps at work and the pre-determined rendezvous and holding points. Ambulance clearance stations and one-way routing systems can also be identified using GIS. At major incidents in the UK, all three ‘blue light’ emergency services (Police, Fire, Ambulance) have predetermined

arrangements for the location of and communication between individual service ISUs. Locations are identified where all three units can set up and operate side by side, to facilitate effective coordination and communication.

As mentioned above, special risk sites identified during pre-event visits and training are located in the GIS by use of a designating symbol or icon, usually a yellow triangle with an exclamation mark within it. This is the universally acknowledged symbol for a hazard. New pre-event planning procedures identify key components of risk sites and buildings. Information gathered for later use includes:

- Gas and Electrical intakes
- Sprinkler controls and Riser connections
- Nearest hydrants and other water supplies
- Access and entry points
- Alarm systems and locations of emergency information
- Firefighting enclosures, lifts and stairs
- High priority actions such as salvage or process shut-down
- Bridgeheads and compartmentation

Copies of plans containing the above information can be used to brief sector commanders and crews performing tasks. Working to the master plan enables better management of crews at the scene. The incident commander has a clear understanding of where sectors are located, who is controlling them and the resources deployed. Tactics can be determined using pre-event plans showing bridgeheads and compartmentation within the building. In historic buildings individual items of furniture, pottery or art can be irreplaceable. Pre-event plans developed in conjunction with the owners can identify the location and safe salvage arrangements for specific items. In essence, everyone on the ground has the opportunity to clearly understand the orientation of the scene and their particular sphere of operation within it.

Plans prepared for fire prevention legislation enforcement can be stored within the system for use in conjunction with the GIS for incident command. The facility now exists to view all plans in 3-D, with the added ability to ‘walk through’ the building on the screen. As has already been stated, plans can be viewed in conjunction with photos of the building, including pre-shot interiors. Digital cameras are used to capture views during the pre-event planning visits and stored on the GIS. Video footage taken before the event can be replayed in the ISU during the incident. This makes it easier for the Incident Commander’s orientation. Where computer storage capacity is considered a problem, images and plans can be stored on CD-ROM and used as appropriate.

Systems are in place that enables data to be transferred from the MCC to the ISU or other mobiles. Fax facilities have existed for some time now but the transfer of computer data to mobile appliances is still relatively rare.

GLOBAL POSITIONING SATELLITE / AUTOMATIC VEHICLE LOCATION SYSTEM (AVLS)

GIS in conjunction with Automatic Vehicle Locating Systems (AVLS) using Global Positioning Satellite (GPS) technology can show the availability and location of the nearest resources to the incident, whether mobile or at station. Dispatch decisions can be made on the basis of this information to ensure the speediest and most appropriate response. Portable GPS units have been used to log the location of hydrants (in the UK all fire hydrants are underground) and to transfer the data onto the GIS for accurate mapping and subsequent location.

GPS/AVLS is in use in some fire Brigades and ambulance services in the UK to track mobile vehicles. In the ambulance service it is also used in combination with GIS and historical incident data to provide a predictive mobilizing tool. This gives the opportunity to deploy limited resources in the most effective way when call volume exceeds availability. AVLS used in conjunction with live traffic management data supplied in real time by the police and highways departments, can enable dynamic routing decisions to be made and details passed to mobile vehicles. Thus avoiding congested routes or road closures.

It is important that Incident Commanders know the deployment of major resources during an incident. GPS/AVLS information can be relayed to the ISU to show where appliances are located during an incident, displayed on the GIS resource map. This can be in the form of a projected image onto the resource board or on a computer screen within the ISU. GIS technology can enable operators to calculate the length of hose lines from major water sources to the incident, or the number of intermediate pumps required in a water relay. Marshalling officers will be able to identify the number and type of appliances at rendezvous or holding points.

CCTV

Traditionally, Incident Commanders have used three methods to gather tactical updates during an incident: first hand, by running round the scene themselves; from sector commanders by use of radio or briefings; or by the use of runners. Close Circuit Television (CCTV) is now more widely used in the Fire Service as an additional source of tactical information. More and more incident support units are being fitted with telescopically mounted CCTV, relaying pictures to screens in the vehicle. Aerial or high rise appliances are now fitted with remote-controlled CCTV relaying signals to the ISU by radio link or cable. The Incident Commander is able to survey large sections of the scene and evaluate performance without leaving the command post.

The Fire Service is also working with the Police to have access to CCTV used in town centres, shopping malls and other urban areas for security purposes. In the UK there is an ever increasing use of CCTV on motorways and other major roads to assist traffic management. Pictures from those sources can now be transmitted to either the MCC or ISU. Consider the benefits of having access to the pictures from both the outside and inside of a shopping mall during an incident in one of the interior units. The locations of each camera, together with its ID can be stored on the GIS map base. Pictures from such units can be viewed within the GIS facility or another screen.

Some fire brigades have small video cameras mounted onto the dashboards of appliances relaying pictures back to the MCC. The pictures can be used to give the MCC better information regarding the incident on arrival. The footage has also been used for fire investigation purposes and as evidence in traffic accidents involving appliances.

Experiments are underway to fit miniature cameras into firefighting helmets. One helmet manufacturer has designed a helmet that will accommodate a small maglite on one side and a camera on the other, both contained within the helmet profile. CCTV has been used to relay pictures to fire and other personnel outside of the incident. Such technology has been used to relay pictures taken by Paramedics at a road traffic accident to the surgeon at the receiving hospital. Advice can then be given to the paramedic as necessary.

HELICOPTER DOWNLINK

The CCTV role has recently been widened to include pictures captured by sophisticated camera equipment now carried on Police helicopters. Nottinghamshire Fire and Rescue Service has acquired radio receivers and monitors that can enable the Incident Commander to view footage shot by the helicopter crew over-flying the scene. The camera technology employed by the Police also includes thermal imaging and infrared imaging, both of which can also be received by the Fire Brigade equipment.

Thermal imaging can be of tremendous value during the hours of darkness to track not only the fire, but also appliances and personnel at the scene. Thermal imaging has also been used successfully to locate the victims of road accidents and light aircraft crashes. Thermal imaging and infrared can assist the Incident Commander to monitor fire spread, its severity and direction of travel. Flying brands, ‘hot-spots’ and secondary fires can also be observed and action taken as appropriate.

THERMAL IMAGING

Currently, at least one appliance in every predetermined attendance to an incident carries a thermal-imaging camera. The units are currently about the size of a camcorder, hand held, battery powered, and viewed through an eyepiece on the camera itself. Conventionally, breathing apparatus teams located fires and victims in dense smoke using this technology. The team being lead by a firefighter carrying the camera. Thermal imaging has also been used to check the unaffected sides of compartment walls for potential fire spread, with crews with hose lines standing by in case.

Thermal-imaging pictures can currently be relayed to monitors outside of the incident via cable. It is hoped that the technology will soon be available to transmit signals by radio link. The most difficult part of that process is overcoming the interference from the structure itself. Internal pictures will not only help the Incident and Sector Commanders, but also the officers responsible for personnel accountability.

The early thermal imaging cameras needed two hands to hold them. Current units are lighter and smaller. A unit that fits onto a Firefighter’s helmet is being evaluated at the moment. This would enable the Firefighter to have both hands free.

PERSONAL ACCOUNTABILITY SYSTEMS / TELEMETRY

Firefighting and other agency personnel must be locatable during an incident. In the UK, outer and inner cordons are sued to control the incident ground and the movement of personnel and other persons in and around it. During firefighting in structures or at other times that breathing apparatus is worn, a second level of control is implemented. This involves the use of personal tallies for each and every breathing apparatus wearer committed to the fire and a recording/timing device called a breathing apparatus control board. An officer is assigned to supervise the wearers using the board and to initiate emergency procedures if either they fail to return to the control point at a predesignated time (governed by the set duration), or if the wearers operate a distress signal themselves. The supervisory officer uses the breathing apparatus control board to log details of the wearer, cylinder content, time due out and area of search.

Systems are currently being tested that will transmit breathing apparatus set and personal data to the control officer outside via a radio link. Set cylinder contents and projected duration, ambient temperature and heart rate details can be transmitted, recorded and monitored by the supervisory officer. Such systems will also be able to provide the Firefighter with the same information in the form of a 'head-up display.' Two-way signal capability enables the supervisory officer to send an evacuation message to the breathing apparatus wearers in case of emergency.

In addition to knowing the whereabouts or major resources such as appliances, technology is available to track personnel during an incident. Normal rolls of every Firefighter at the incident are kept on ISUs to ensure that, in the event of accident, a speedy roll call can be achieved. This can currently be achieved in two ways. Firstly, by the use of bar code scanning technology. Every fire service individual on the site has a tally incorporating personal details read by the scanner on the ISU and at the entrance to the cordon. These log attendance at the incident and passage through the cordons.

An alternative to bar coding technology is the 'smart patch.' Information is stored in a programmable chip that can be sewn into the firefighter's tunic. The 'patch' is recognized as the individual passes through a mobile scanner. All information is stored on a computer on the ISU. In addition to roll call and movement within the cordons, the patches can hold personal information. Patches can also store medical details and specialist skills.

CONCLUSION

The integration of static, pre-event information with dynamic information provided during the incident is crucial to the successful management of any operational incident. Spatial technology and document management enable such information to be gathered, stored and used by the on scene commander. The effective management of all on scene resources is a determinant of successful incident outcome. GIS provides the facility to store and use relevant information gathered from a number of diverse sources and employing different technologies.

It would be encouraging to think that all of the above technologies are both widely available and in use in every brigade within the UK fire service. Whilst it is true to say that the individual components are available and in use, it would not be true to say that they are all used together. Many fire brigades have one or more of the above elements.

GIS is relatively new to the fire service and its potential has not been fully explored nor utilized. It is true to say that there are those who previously failed to recognize the value of such technology in operational planning and incident command. GIS is also used to analyze incident data to provide information with which to plan fire safety education programs by identification of at-risk population groups and areas.